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Phase Transitions as a Novel Mechanism for High-Speed Energy Storage[1]

JERRY BERNHOLC, NC State University, Raleigh, NC 27695-7518

In many energy applications there is an urgent need to store and quickly discharge large amounts of electrical energy. Since capacitors can be discharged far quicker than batteries and fuel cells, they have much higher power densities. At present, highly insulating polymers with large breakdown fields, such as polypropylene, are the dielectrics of choice in high-power capacitors. However, their energy densities are quite low because of small dielectric constants. Ferroelectric polymers from the PVDF family have significantly larger dielectric constants, yet their energy densities are still rather low. This can be traced to early saturation of their displacement fields with the applied electric field, and to somewhat lower breakdown fields. However, an admixture of a small amount of another polymer, such as CTFE, results in a dramatic increase in the stored energy [1]. We show that this highly non-linear increase in the energy density is due to the formation of disordered nanodomains with different copolymer concentrations, which undergo first-order non-polar to polar phase transitions with an increase of the applied field. The resulting energy density profile reproduces well the experimental data, while its variation with co-polymer concentration and distribution suggest avenues for additional substantial improvements in the stored energy [2]. Most recently, we have identified a low-activation-energy pathway for these successive phase transformations [3]. It provides further confirmation of the viability of the suggested energy storage mechanism and also enables fine-tuning of the kinetics of energy release by informed choices of suitable co-polymers.

[1] Chu et al, Science 313, 334 (2006).
0pt] [2] V. Ranjan L. Yu, M. Buongiorno-Nardelli, and J. Bernholc, PRL 99, 047801 (2007).
[3] V. Ranjan, M. Buongiorno Nardelli, and J. Bernholc, PRL 108, 087802 (2012).

[1]In collaboration with V. Ranjan, L. Yu, M. Buongiorno Nardelli and R. Dong.